A Comparative study on Cascaded Multilevel Inverter and Modular Multilevel Inverter with Reduced Switches

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***Abstract*:- In recent trends, different multilevel topologies came into the way of life. But the base is cascaded h-bridge multilevel inverter. In multilevel converters the output can be obtained by combine quite a lot of DC voltage sources. In order to improve the output excellence and to obtain power quality research focusing on higher number of levels at output. However when the number of levels increases more number of DC sources and switches required. These issues become a key point to the researchers. This paper giving comparative study of conventional cascaded H-bridge (CHB) and modular multilevel inverter.**

Keywords: Multilevelinverter, Submultilevel level, Unidirectional and Bidirectional switch, less number of switches.

I. INTRODUCTION

The technology of power electronics is effective conversion as well as control of electrical power by means of devices such as PE semiconductor switches. The main purpose of power electronics is for controlling the electrical energy flow from source to load [1]. The word 'inverter' in PE denotes the conversion unit which converts a dc voltage source or a dc current source into ac voltage or current of required magnitude as well as frequency. The output voltage waveforms of ideal inverters should be sinusoidal. But in practical the waveforms of inverters are non-sinusoidal because of harmonic content present at the output. Especially for high power application, less distorted sinusoidal wave forms are needed; this can be accomplished with power semiconductor devices such as IGBT, MOSFET, GTO, and MCT etc. The content of harmonics at output voltage can be minimized considerably by by proper switching's which are generated by using pulse-width modulation (PMW) control techniques within the inverter [2-4].

A variable output voltage can be obtain by changing the dc input voltage and maintaining the inverter gain constant. The variable output voltage can be synthesized by changing the gain of the inverter when operating with fixed DC input voltage.. The gain of the inverter could be defined as the ratio of the AC output magnitude to DC input magnitude [5].

Nowadays, more industrial equipment required high power and medium voltages. The MLI is the best choice for high power and medium voltage applications. The advantage of MLI is less common mode voltage, lower switching losses, low harmonic distortion, and availability of high output power from intermediate voltage source like batteries, super capacitors, pv cells. In the MLI the arrangement of switches and control signals are very important [6].

Multilevel inverters classified into three types i.e., diode clamped multilevel inverter (DC-MLI), flying capacitor multilevel inverter (FC-MLI) and cascaded h-bridge multilevel inverter (CHB-MLI). Among these topologies CHB-MLI gives the high output voltage as well as power levels and it can provide high reliability owing to its modular topology. The diode-clamped inverter consists of m-1 capacitors on the source side and generates m levels at output voltage. But the balancing of capacitor voltage quite complex hence DC-MLI has been limited only to 3-level. In flying capacitor (FC-MLI) the switching cells are clamped with series connection of capacitors. The main shortcoming of this configuration is high figure of capacitors tend to high cost and more difficulty [7]. As a final point CHB-MLI consists of series of H-bridge inverter units. CHB-MLI can attain higher number of Power and voltage levels than twice the count of DC sources. CH-BMLI has been applied in the areas where large-power required and also in photovoltaic systems, active power filters, FACTS, uninterruptible power supplies, reactive power compensators magnetic resonance imaging. Besides present trending applications of multilevel power converters is electric drive vehicles where the traction motor is run by batteries. The major downside of CH-BMLI is more add up of switches and DC links essential to raise the output levels. This paper focused on multilevel inverter topology. This work recommends novel module inverter structure with least amount of components [8].

II. CONVENTIONAL CHB-MLI

CHB type multilevel inverters can be work in symmetrical and asymmetrical structure. In symmetrical configuration all DC sources are having same magnitude and produces output voltage equal to the summation of DC sources. This is not clearly an efficient topology to work with MLI. Because to produce more output voltage levels it requires high count of semiconductor switches and DC sources. And nowadays solar output voltage considering as DC input to the MLI [9-10]. In this case it is difficult to maintain all DC source magnitudes equal and invariable. at that time the controlling of inverter switching’s become difficult. Above difficulties can overcome by selecting asymmetrical configuration. The main fetching of asymmetrical configuration is efficient working with unequal DC sources and the count of generated steps at output side will increase compared to symmetrical configuration with same number of sources. This will lead to power quality of output. Variation in DC voltage cannot be a problem.

1. Symmetrical structure

In symmetrical structure of CHB all sources are maintaining the same amount of magnitudes and the output voltage is the summation of voltage sources. In general cascade H bridge structure to generate 17 levels, 8 sources and 32 switches required [11]. Fig.1 shows the symmetrical structure of CHB. Since this topology consists of series of power conversion cells, the voltage and power can be easily scaled. The magnitudes for 8 voltage sources are taken as below

$$V_1 = V_2 = V_3 = V_4 = V_5 = V_6 = V_7 = V_8 = V_{dc} \qquad (1)$$

The number of output levels generated at output side can be calculated by

$$V_{out} = 2n+1 \text{ levels} \qquad (2)$$

Here n= number of bridges
Hence 2*8+1=17 level output is going to generate at output side.

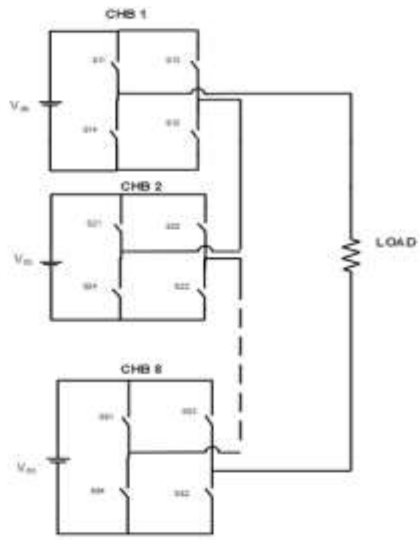


Fig. 1. Symmetrical Cascaded H-bridge with 8 sources and 32 switches

2. Asymmetrical structure

The DC voltages of the H-bridge power cells introduce in the previous section all are same. Alternatively by selecting voltage levels of power cells unequal can generate 17 levels but reduced switches and power cells. The switching patterns has generated that renders an equal voltage stepped output waveform [12]. Here 3 DC voltage sources and 12 switches has been used to generate 17 level output. The voltage of the power cells considered as

$$V_1 = V_{dc}$$
$$V_2 = 3V_{dc}$$
$$V_3 = 4V_{dc} \quad (3)$$

The voltage waveform constitute of 8 positive levels one zero level and 8 negative levels i.e., $8V_{dc}$, $7V_{dc}$, $6V_{dc}$, $5V_{dc}$, 4 V_{dc}, $3V_{dc}$, $2V_{dc}$, V_{dc}, 0, - V_{dc}, $-2V_{dc}$, $-3V_{dc}$, $-4V_{dc}$, $-5V_{dc}$, -6 V_{dc}, $-7V_{dc}$, $-8V_{dc}$.. In this PWM technique used to generate 17-level and 8-carrier waves used in different magnitudes and one sinusoidal reference voltage. Fig.2 exposed the asymmetrical structure of Cascaded H-bridge.

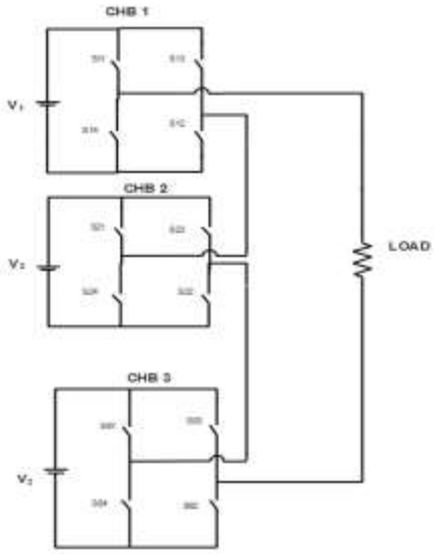


Fig. 2. Asymmetrical 17 level configuration of cascaded H-bridge with 3 DC voltage sources and 12 switches

III. PROPOSED CASCADED STRUCTURE AND SWITCHING PATTERNS

By connection of ‘ m’ No. of the module inverter to introduce a new cascaded structure ,the number of counts likes switches, IGBTs; and No.of DC links is obtained by using below formulae

$$N_{switch} = 8m; N_{IGBT} = 10m \text{ and } N_{dc\ links} = 4m$$

In the proposed topology 4 dc links were used and voltages of the DC links considered as below:

$$V_1=V_2=V_{dc} \quad (4)$$

$$V_3=V_4=3V_{dc} \quad (5)$$

The generated output voltage levels are obtained as follows:

$$N_{level} = 8m+1 \quad (6)$$

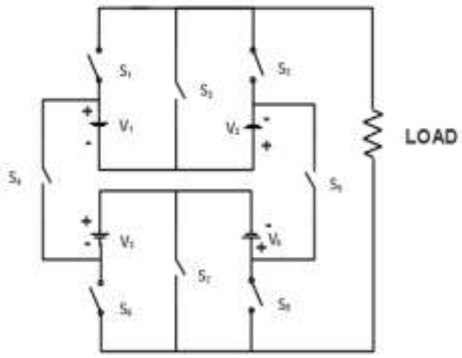


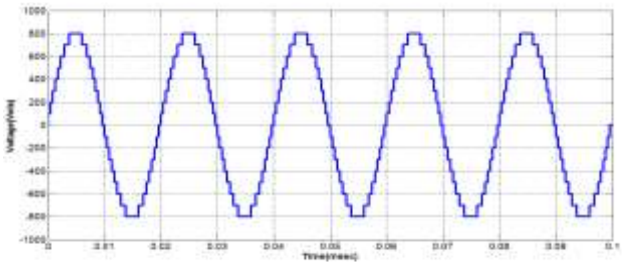
Fig. 3. Proposed structure of Multilevel inverter using 4 DC voltage sources and 8 switches

Fig.3 shows the proposed structure of multilevel inverter. V_1 ,V_2 ,V_3 ,V_4 are the sources and S_1,S_2,S_3,S_4,S_5,S_6,S_7,S_8 are the switches. In that S_2 and S_7 switches are bidirectional switches and rest of the switches are unidirectional switches. Single IGBT switch used for unidirectional switch and two IGBT switches connected in anti-parallel used for bidirectional switches.

IV. SIMULATION RESULTS

In this section all MLI has been simulated by using MATLAB software. Thus inverter gives 17- level at its output with peak amplitude of 800V. The output voltage frequency is set to 50Hz. And load consider as R = 150Ω.

Fig. 4 shows the output voltages of symmetrical cascaded H-bridge, asymmetrical cascade H-bridge and proposed cascaded H-bridge for the modulation index 0.9 (high). Similarly Fig.5 shows the output voltages of symmetrical cascaded H-bridge, asymmetrical cascade H-bridge and proposed cascaded H-bridge for the modulation index 0.25 (low). Fig.6 shows the THD voltages of symmetrical cascaded H-bridge, asymmetrical cascade H-bridge and proposed cascaded H-bridge for the modulation index 0.9 (high). Fig.7 shows the THD voltages of symmetrical cascaded H-bridge, asymmetrical cascade H-bridge and proposed cascaded H-bridge for the modulation index 0.5 (medium). Fig.8 shows the THD voltages of symmetrical cascaded H-bridge, asymmetrical cascade H-bridge and proposed cascaded H-bridge for the modulation index 0.25 (low).And it is clearly shown that the total harmonic distortion is considerably reduced and switches, sources count also decreased in proposed structure of multilevel inverter. Table I gives the complete analysis of results between different topologies.



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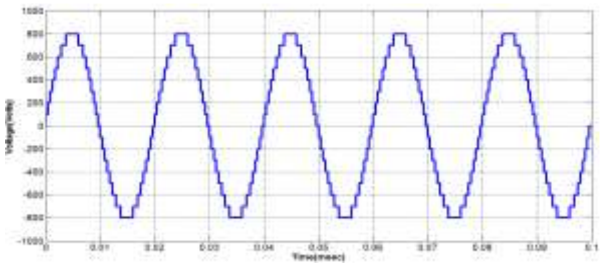

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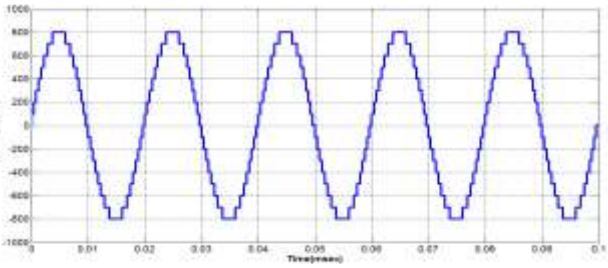
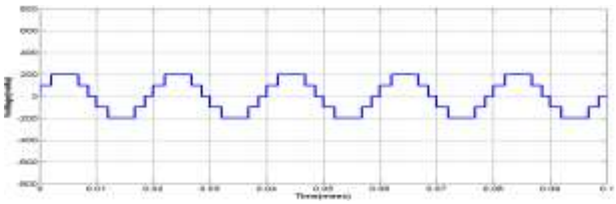


(c)

Fig. 4. Output voltages for 0.9 Modulation index (a) Symmetrical Cascaded H-bridge with 8 sources and 32 switches (b) asymmetrical Cascaded H-bridge with 3 sources and 12 switches (c) proposed Cascaded H-bridge with 4 sources and 8 switches



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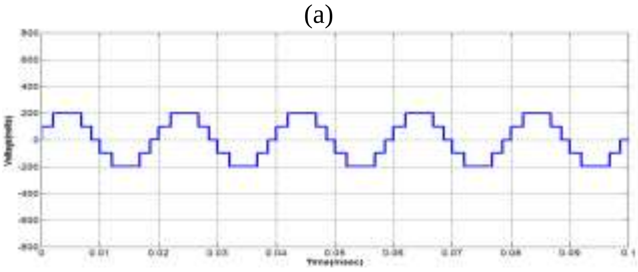

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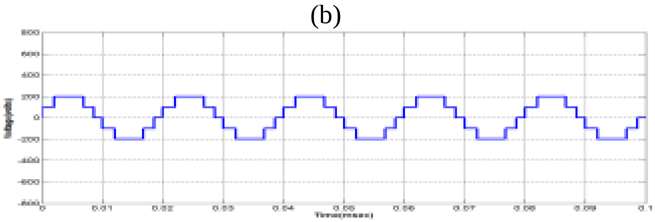

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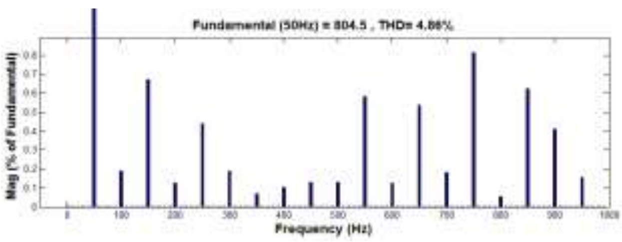
Fig.5. Output voltages for 0.25 Modulation index (a) Symmetrical Cascaded H-bridge with 8 sources and 32 switches (b) asymmetrical Cascaded H-bridge with 3 sources and 12 switches (c) proposed Cascaded H-bridge with 4 sources and 8 switches



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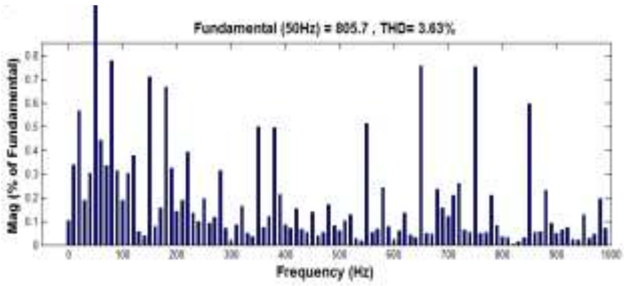

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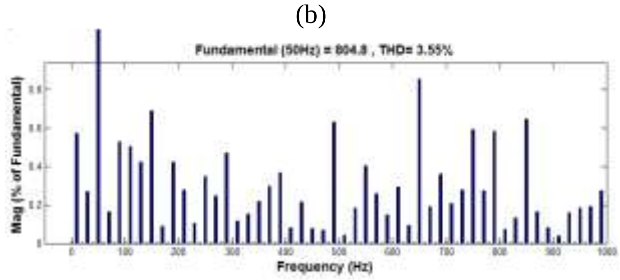
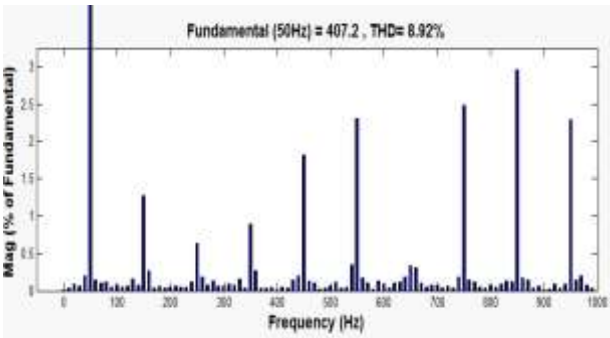


(c)

Fig.6 Total Harmonic Distortion for 0.9 Modulation index
(a) Symmetrical Cascaded H-bridge with 8 sources and 32 switches
(b) asymmetrical Cascaded H-bridge with 3 sources and 12 switches
(c) proposed Cascaded H-bridge with 4 sources and 8 switches



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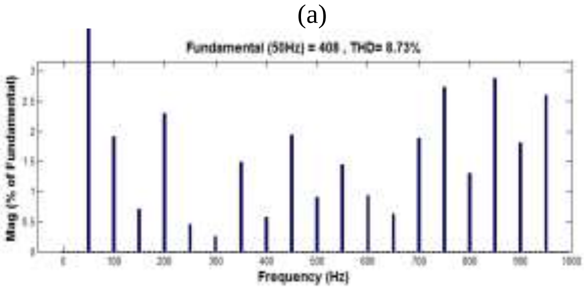

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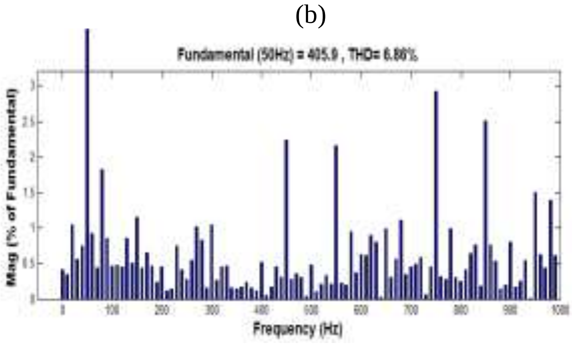

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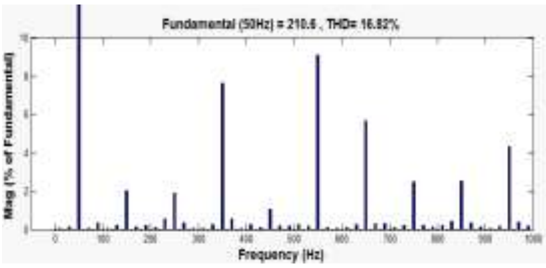
Fig.7 Total Harmonic Distortion for 0.5 Modulation index
(a) Symmetrical Cascaded H-bridge with 8 sources and 32 switches
(b) asymmetrical Cascaded H-bridge with 3 sources and 12 switches
(c) proposed Cascaded H-bridge with 4 sources and 8 switches



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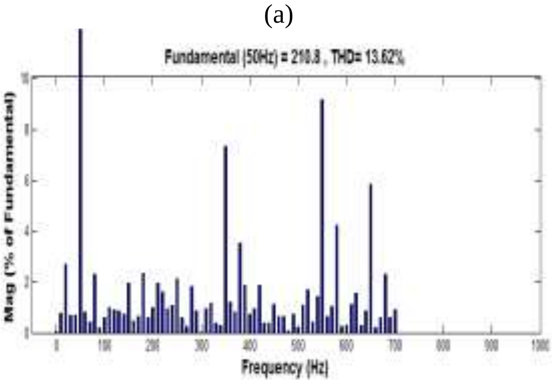

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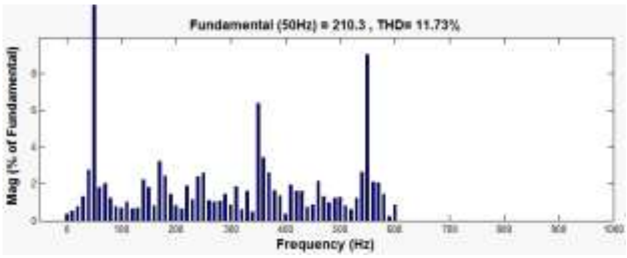

(c)

Fig.8 Total Harmonic Distortion for 0.25 Modulation index
(a) Symmetrical Cascaded H-bridge with 8 sources and 32 switches
(b) asymmetrical Cascaded H-bridge with 3 sources and 12 switches
(c) proposed Cascaded H-bridge with 4 sources and 8 switches

Table I:- RESULT EVALUATION OF DIFFERENT TOPOLOGIES

Type of CHB	No. of levels	No. of Sources	No. of Switches	Modulation Index	Voltage (V)	% THD
Conventional CHB (symmetrical)	17	8	32	0.9	800	4.8
				0.5	400	8.9
				0.25	200	16.8
Conventional CHB (Asymmetrical)	17	3	12	0.9	800	3.63
				0.5	400	8.7
				0.25	200	13.6
Proposed CHB	17	4	8	0.9	800	3.5
				0.5	400	6.8
				0.25	200	11.7

VII. CONCLUSION

This work suggested a new sub-MLI by reducing the switches and DC links. In general symmetrical CHB MLI to obtain 17-level 8 DC links and 32 switches required and in asymmetrical configuration 3 DC links and 12 switches are required. In proposed configuration switches reduced to 8 and 4 DC links were used. Results are significantly improved in proposed topology and also verified through MATLAB/Simulink. Table 1 gives complete analysis of the work.

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